

UNS R54790

TITANIUM ALLOY BARS AND FORGINGS
11Sn - 5.0Zr - 2.3Al - 1.0Mo - 0.21Si
Solution and Precipitation Heat Treated

1. SCOPE:

1.1 Form: This specification covers a titanium alloy in the form of bars, wire, forgings, and forging stock.

1.2 Application: Primarily for parts requiring high strength and toughness and good creep resistance up to 900°F (480°C). Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking; ARP 982 recommends practices to minimize such conditions.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) and Aerospace Recommended Practices (ARP) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2241 - Tolerances, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire

AMS 2249 - Chemical Check Analysis Limits, Titanium and Titanium Alloys

AMS 2350 - Standards and Test Methods

AMS 2375 - Control of Forgings Requiring First Article Approval

AMS 2808 - Identification, Forgings

2.1.2 Aerospace Recommended Practices:

ARP 982 - Minimizing Stress Corrosion in Wrought Titanium Alloy Products

SAE Technical Board rules provide that: "All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade or their use by governmental agencies is entirely voluntary. There is no agreement to adhere to any SAE standard or recommended practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Board and its Committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents."

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19130.

- ASTM E8 - Tension Testing of Metallic Materials
- ASTM E21 - Elevated Temperature Tension Tests of Metallic Materials
- ASTM E120 - Chemical Analysis of Titanium and Titanium Alloys
- ASTM E139 - Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
- ASTM E292 - Conducting Time-for-Rupture Notch Tension Tests of Materials

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

2.3.2 Military Standards:

MIL-STD-163 - Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E120, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other analytical methods approved by purchaser:

	min	max	
Tin	10.50	11.50	
Zirconium	4.00	6.00	
Aluminum	2.00	2.50	
Molybdenum	0.80	1.20	
Silicon	0.15	0.27	
Oxygen	--	0.15	
Iron	--	0.12	
Carbon	--	0.04	
Nitrogen	--	0.04	(400 ppm)
Hydrogen	--	0.0125	(125 ppm)
Yttrium	--	0.005	(50 ppm)
Residual Elements, each (3.1.1)	--	0.10	
Residual Elements, total (3.1.1)	--	0.30	
Titanium	remainder		

3.1.1 Determination not required for routine acceptance.

3.1.2 Check Analysis: Composition variations shall meet the requirements of AMS 2249; no variation over maximum will be permitted for yttrium, unless otherwise agreed upon by purchaser and vendor.

3.2 Condition: The product shall be supplied in the following condition:

3.2.1 Bars: Hot finished with or without subsequent cold reduction, solution and precipitation heat treated, and descaled.

3.2.2 Wire: Cold drawn, solution and precipitation heat treated, and descaled.

3.2.3 Forgings: Solution and precipitation heat treated and descaled.

3.2.4 Forging Stock: As ordered by the forging manufacturer.

3.3 Heat Treatment: Bars, wire, and forgings shall be solution heat treated by heating to $1650^{\circ}\text{F} + 25$ ($900^{\circ}\text{C} + 15$), holding at heat for 60 min. + 5, and cooling at a rate equivalent to air cool or faster and precipitation heat treated by heating to $930^{\circ}\text{F} + 15$ ($500^{\circ}\text{C} + 8$), holding at heat for 24 hr + 0.5, and cooling in air.

3.4 Properties: The product shall conform to the following requirements:

3.4.1 Bars, Wire, and Forgings: Product 1.00 in. (25.0 mm) and under in nominal diameter or distance between parallel sides shall have the following properties; product over 1.00 in. (25.0 mm) in nominal diameter or distance between parallel sides shall have properties as agreed upon by purchaser and vendor:

3.4.1.1 Tensile Properties: The following requirements apply in both the longitudinal and transverse directions but tests in the transverse direction need be made only on product from which a specimen not less than 2.50 in. (62.5 mm) in length can be taken. Tests in the longitudinal direction are not required on product tested in the transverse direction.

3.4.1.1.1 At Room Temperature: Shall be as follows, determined in accordance with ASTM E8 with the rate of strain maintained at 0.003 - 0.007 in. per in. per min. (0.003 - 0.007 (mm/mm)/min.) through the yield strength and then increased so as to produce failure in approximately one additional minute; when a dispute occurs between purchaser and vendor over the yield strength values, a referee test shall be performed on a machine having a strain rate pacer, using a rate of 0.005 in. per in. per min. (0.005 (mm/mm)/min.) through the yield strength and a minimum cross head speed of 0.10 in. (2.5 mm) per min. above the yield strength.

Tensile Strength, min	145,000 psi (1000 MPa)
Yield Strength at 0.2% Offset, min	135,000 psi (930 MPa)
Elongation in 4D, min	10%
Reduction of Area, min	20%

3.4.1.1.2 At 800°F (427°C): Shall be as follows, determined in accordance with ASTM E21 on specimens heated to 800°F ± 5 (427°C ± 3), held at heat for 20 - 30 min. before testing, and tested at 800°F ± 5 (427°C ± 3):

Tensile Strength, min	105,000 psi (725 MPa)
Yield Strength at 0.2% Offset, min	80,000 psi (550 MPa)
Elongation in 4D, min	15%
Reduction of Area, min	30%

3.4.1.2 Stress-Rupture Properties: Shall be as specified in 3.4.1.2.1 and 3.4.1.2.2; room-temperature tests shall be conducted in accordance with ASTM E292 and 1000°F (538°C) tests in accordance with ASTM E139.

3.4.1.2.1 Room-Temperature Notched: A specimen machined to the dimensions shown in Fig. 1 and Table I, maintained at room temperature while an axial stress of 165,000 psi (1140 MPa) is applied continuously, shall not rupture in less than 5 hours. The initial stress may be less than 165,000 psi (1140 MPa) and increased to 165,000 psi (1140 MPa) based on the initial diameter at root of notch, in increments of 10,000 psi (70 MPa) at intervals of not less than 5 hours.

3.4.1.2.2 At 1000°F (538°C): A tensile specimen, maintained at 1000°F ± 3 (538°C ± 2) while a load sufficient to produce an initial axial stress of 70,000 psi (485 MPa) is applied continuously, shall not rupture in less than 23 hours. The test shall be continued to rupture without change of load. Elongation after rupture, measured at room temperature, shall be not less than 10% in 4D.

3.4.1.2.2.1 The test of 3.4.1.2.2 may be conducted using a load higher than required to produce an initial axial stress of 70,000 psi (485 MPa), but load shall not be changed while test is in progress. Time to rupture and elongation requirements shall be as specified in 3.4.1.2.2.

3.4.1.2.2.2 When permitted by purchaser, the test of 3.4.1.2.2 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 70,000 psi (485 MPa) shall be used to rupture or for 23 hr, whichever occurs first. After the 23 hr and at intervals of 8 - 16 hr, preferably 8 - 10 hr, thereafter, the stress shall be increased in increments of 5000 psi (35 MPa). Time to rupture and elongation requirements shall be as specified in 3.4.1.2.2.

3.4.1.3 Creep Properties at 800°F (427°C): A tensile specimen, maintained at 800°F ± 3 (427°C ± 2) while a load sufficient to produce an initial axial stress of 70,000 psi (485 MPa) is applied continuously for 100 hr, shall not exceed 0.2% creep elongation. Gage dimensions of specimens and techniques used to measure creep shall be as agreed upon by purchaser and vendor. Tests shall be conducted in accordance with ASTM E139.

- 3.4.1.4 Microstructure: Shall be essentially that resulting from alpha-beta processing. The specific alpha + beta microstructure shall not be cause for rejection unless standards for acceptance have been agreed upon by purchaser and vendor. Microstructure shall be cause for rejection if any areas of a forging exhibit an all-transformed beta microstructure.
- 3.4.1.5 Surface Contamination: Except as specified in 3.4.1.5.1 and 3.4.1.5.2, the product shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, determined by microscopic examination at not lower than 100X magnification or other method agreed upon by purchaser and vendor.
- 3.4.1.5.1 An oxygen-rich layer not greater than 0.001 in. (0.03 mm) in depth will be permitted on bars other than round.
- 3.4.1.5.2 When permitted by purchaser, forgings to be machined all over may have an oxygen-rich layer provided such layer is removable within the machining allowance on the forging.
- 3.4.2 Forging Stock: When a sample of stock is forged to a test coupon and heat treated as in 3.3, specimens taken from the heat treated coupon shall conform to the requirements of 3.4.1.1, 3.4.1.2, and 3.4.1.3. If test specimens taken from the stock after heat treatment as in 3.3 conform to the requirements of 3.4.1.1, 3.4.1.2, and 3.4.1.3, the tests shall be accepted as equivalent to tests of a forged coupon.
- 3.5 Quality:
- 3.5.1 Alloy shall be produced by multiple melting using consumable electrode practice; at least one of the melting cycles shall be under vacuum.
- 3.5.2 The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from internal and external imperfections detrimental to usage of the product.
- 3.6 Tolerances: Unless otherwise specified, tolerances for bars and wire shall conform to all applicable requirements of AMS 2241.

4. QUALITY ASSURANCE PROVISIONS:

- 4.1 Responsibility for Inspection: The vendor of the product shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.
- 4.2 Classification of Tests:

AMS 4974A

- 4.2.1 Acceptance Tests: Tests to determine conformance to the following requirements are classified as acceptance tests and shall be performed on each heat or lot as applicable:
- 4.2.1.1 Composition (3.1) of each heat.
 - 4.2.1.2 Room-temperature tensile properties (3.4.1.1.1), microstructure (3.4.1.4), and surface contamination (3.4.1.5) of each lot of bars, wire, and forgings.
 - 4.2.1.3 Tolerances (3.6) of each lot of bars and wire.
- 4.2.2 Periodic Tests: Tests to determine conformance to the following requirements are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser:
- 4.2.2.1 Tensile properties at 800°F (427°C) (3.4.1.1.2), stress-rupture properties (3.4.1.2.1 and 3.4.1.2.2), and creep properties (3.4.1.3) of bars, wire, and forgings.
 - 4.2.2.2 Ability of forging stock to develop required properties (3.4.2).
- 4.2.3 Preproduction Tests: Tests of forgings to determine conformance to all applicable technical requirements of this specification when AMS 2375 is specified are classified as preproduction tests and shall be performed on the first-article shipment of a forging to a purchaser, when a change in material and/or processing requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.
- 4.2.3.1 For direct U.S. Military procurement of forgings, substantiating test data and, when requested, preproduction forgings shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.
- 4.3 Sampling: Shall be in accordance with the following; a lot shall be all product of the same nominal size from the same heat processed at the same time:
- 4.3.1 For Acceptance Tests:
 - 4.3.1.1 Composition: One sample from each heat except that for hydrogen determination one sample from each lot, obtained after thermal and chemical processing is completed.

- 4.3.1.2 Tensile Properties: At least one sample from bars and wire from each lot. The number, location, and orientation of samples from forgings shall be as agreed upon by purchaser and vendor.
- 4.3.1.3 Other Requirements: As agreed upon by purchaser and vendor.
- 4.3.2 For Periodic Tests and Preproduction Tests: As agreed upon by purchaser and vendor.
- 4.3.2.1 Specimens for room-temperature notched stress-rupture tests shall be taken in the longitudinal direction from bars and wire and in the tangential direction from forgings.
- 4.4 Approval: When specified, approval and control of forgings shall be in accordance with AMS 2375.
- 4.5 Reports:
- 4.5.1 The vendor of the product shall furnish with each shipment three copies of a report showing the results of tests for chemical composition of each heat and for the hydrogen content and tensile properties of each lot, and stating that the product conforms to the other technical requirements of this specification. This report shall include the purchase order number, heat number, AMS 4974A, size, and quantity from each heat. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.
- 4.5.2 The vendor of finished or semi-finished parts shall furnish with each shipment three copies of a report showing the purchase order number, AMS 4974A, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and shall include in the report either a statement that the material conforms or copies of laboratory reports showing the results of tests to determine conformance.
- 4.5.3 Resampling and Retesting: If any specimen used in the above tests fails to meet the specified requirements, disposition of the product may be based on the results of testing three additional specimens for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented and no additional testing shall be permitted. Results of all tests shall be reported.
5. PREPARATION FOR DELIVERY:
- 5.1 Identification: The product shall be identified as follows:

5.1.1 Bars and Wire:

- 5.1.1.1 Each straight bar over 0.500 in. (12.50 mm) in nominal diameter or least width of flat surface shall be marked in a row of characters recurring at intervals not greater than 3 ft (900 mm) with AMS 4974A, heat number, and manufacturer's identification. The characters shall be of such size as to be legible, shall be applied using a suitable marking fluid whose residue shall contain not more than traces of halogen-bearing compounds, and shall be removable in hot alkaline cleaning solution without rubbing. The markings shall have no deleterious effect on the product or its performance and shall be sufficiently stable to withstand normal handling.
- 5.1.1.2 Straight bars and wire 0.500 in. (12.50 mm) and under in nominal diameter or least width of flat surface shall be securely bundled and identified by a durable tag marked with the purchase order number, AMS 4974A, heat number, nominal size, and manufacturer's identification and attached to each bundle or shall be boxed and the box marked with the same information.
- 5.1.1.3 Coiled bars and wire shall be securely bundled and identified by a durable tag marked with the purchase order number, AMS 4974A, heat number, nominal size, and manufacturer's identification and attached to each coil or shall be boxed and the box marked with the same information.

5.1.2 Forgings: In accordance with AMS 2808.

5.1.3 Forging Stock: As agreed upon by purchaser and vendor.

5.2 Packaging:

- 5.2.1 The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.
- 5.2.2 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-163, Level A or Level C, as specified in the request for procurement. Commercial packaging as in 5.2.1 will be acceptable if it meets the requirements of Level C.

6. ACKNOWLEDGMENT: A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase order.

7. REJECTIONS: Material not conforming to this specification or to modifications authorized by purchaser will be subject to rejection.